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Memo

date: *December 18, 2009*

to: *RSC*

from: *D. Beavis* DB

subject: *Potential Dose near RHIC Emergency Ventilation Ducts*

A simple analysis will be given for the potential dose near RHIC ventilation ducts. The discussion below is based on the RHIC SAD[1] Table 4-G-1, which is a summary of the analysis[2] of A. J. Stevens and P. Gollon. The results presented in the SAD will be extended to both low energy operations and upgrades of RHIC beam Intensity. Recommendations will be made to reduce the risk of excess exposure from the ventilation ducts.

RHIC operations at low energy may occur in FY2010 operations for a period of 2-6 weeks at several low energies. The largest uncertainty in the dose estimates for low energy operations comes from the loss estimates, knowledge of the loss locations for chronic losses, and the efficiency of the collimation system for low energy injection and store. Information gained from the short low energy runs should provide adequate data to ensure future long runs at low energy are possible and ALARA.

Estimating the dose from higher intensity and slightly higher energy beams is straight forward. It has been suggested that future upgrades could increase the beam intensity by a factor of two. The maximum beam energy may be able to be increased by 30%. The losses under these upgraded conditions will be assumed to be the same as considered in the RHIC SAD except that a factor of 2.5 will be used to account for the possible intensity and energy increases.

The potential doses for the various ventilation ducts are listed in Table I. When there are cases of two similar type ducts, the one with the larger dose was left in the table from the RHIC SAD and the other one removed for brevity. Some of the entries in the table are for typical ducts. An actual duct may have a somewhat different dose. The Design Base Accident (DBA) or Maximum Credible Incident (MCI) (column 3 in Table I) assumes half of the full energy proton beam interacts at the worst possible location for the duct. The dose given in the table does not include the dose that penetrates directly through the berm, which is of the order[3] of 60 mrem.

Intensity upgrades would have several classes of ventilation ducts exceed the criteria established[5] by an RSC subcommittee for RHIC upgrades. The higher doses are given in Table I column 4. The most practical method may be to place the ventilation ducts into a fenced areas with a locked gate. A factor of approximately 15 in reduced dose is achieved by having a barrier at twice the radius of the vent pipe. Basically each vent would require a fence of about 8 feet on each side to provide adequate dose reduction. Table II lists the ventilation ducts that are already inside locked locations. Table III lists the ducts that are not in secured areas. There are 44 such ducts. The expense to enclose these ventilation ducts inside locked fences is expected to be modest and would prevent undue exposure in the event of a large beam fault.

The doses near a ventilation duct from a MCI at low energy are substantially lower than full energy operations. However, because of the larger chronic beam losses the issue of chronic exposure must be considered.

The RHIC Project did not compute the potential chronic dose exposure for the ventilations ducts. The chronic exposure was assumed to be small compared to the exposure due to a large beam fault. Harrison and Stevens[3] estimated 2.8% of the Au beam lost would be lost in a series of distributed locations, referred to as "other points", including the high beta quads. Most of the locations with anticipated high loss locations were located under secured fences. Ventilation shafts near to these anticipated loss locations would therefore be inside secured fence.

The chronic exposure near a ventilation duct can be estimated by assuming a fraction of the beam losses occurs near the duct and using the results in Table I column 3. The RHIC SAD assumed[5] there would be 2400 fills per year. If 1% of the Au beam loss listed as lost in "other places" of reference 3 is assumed to scrap near a duct then that duct would have a chronic exposure of 1.9 times that given in Table 1 for a DBA (column 3). If one applies aa occupancy factor of 1/16 then the chronic dose would be less than 60 mrem in a year. The 1% assumption is probably conservative for most ventilation ducts and an occupancy factor of 1/16 is also probably conservative. This analysis suggests enclosing the ventilation ducts within fenced areas should be considered even without intensity and energy upgrades. The loss distribution for previous runs of Au and protons should be reviewed so that recent operating experience can be used.

Table I: Ventilation Ducts

Case	Archetype description	SAD DBA Dose at duct cover (mrem)	DBA Dose intensity upgrade (mrem)	3.85 GeV all losses for 1 hr (mrem)	Weekly dose at 3.85 GeV all losses (mrem)	Weekly dose 3.85 GeV 10% loss with 1/16 occupancy
A	Sextant 3 concrete	27	68	4.6	770	4.9
B-2	16 ft plate arch	475	1200	81	11,110	69
C	20 ft arch plate	298	750	51	8,600	54
D-2	26 ft arch plate	136	340	23	4,900	24
E	Structure at 4 O'clock	326	820	55	9,360	59
F-1	Injection sextant 5,7	192	480	33	5,540	35
G-1	Injection wide angle	311	780	53	8,840	55
H	RF cavity sextant 5	103	260	17	2,950	18
I-2	Alcove A&C	411	1030	70	11,800	74
J-2	Alcove B	83	210	14	2,340	15

An estimate of beam losses for injection and store for several low energies has been provided by T. Satogata[6]. The worst case in integrated losses is for the beam energy of 3.85 GeV. As a worst

Table II: Ducts that exit the berm in locked areas

Duct	Duct	Duct
1EF3	5AV2	7AV4
1EF4	5AV3	7AV5
2XEF1	6EXF1	8XEF1
2XAV1	6EXF2	8XSF1
2XAV2	6XAV1	8AV0
3EF3	6XAV2	8AV1
4XEF1	6AV1	8AV2
4XEF2	6AV2	8AV3
4XAV1	7AV2	12XEF1
	7AV3	12XEF2

Table III: Ducts that exit in unsecured Controlled Areas on the RHIC Berm

Duct	Duct	Duct
1EF1	4XAV3	7EF2
1AV1	4EF1	8EF1
1EF2	5EF1	8AV4
1AV2	5AV1	9EF1
1AV3	5EF2	9AV1
2EF1	5EF3	9EF2
2AV1	5EF4	9AV2
2EF2	5AV2	9AV3
2AV2	5AV3	9AV4
3EF1	6EF1	10XSF1
3AV1	6EF2	10XEF1
3EF2	6EF3	10XEF2
3AV2	6AV3	10XSF2
3AV3	7EF1	10AV1
4XAV2	7AV1	

case we have assumed all beam losses in a single ring will be lost adjacent to the ventilation duct being considered. Clearly this should provide an extreme upper limit on the potential exposure. The numbers are presented for the dose in an hour (Column 5) and dose in a week (column 6). It can be seen that these potential exposures are quite large. The 100% loss near a particular duct is not credible but allows for easy scaling. Column 7 of Table I provides the weekly dose exposure at a vent assuming 10% of the beam losses occur adjacent to the duct and the area is occupied

1/16 of the time that beam is operating. It is assumed that the beam is operating 168 hours per week (100% uptime). This potential level of exposure seems to be manageable considering the conservative value assigned to the beam loss, but is large for a Controlled Area without a TLD required. As already noted once a person is several feet away from the ventilation duct the potential exposure drops over an order of magnitude. The most likely risk for exposure would be to personnel sent to work on the ventilation duct. Work controls could help reduce that risk. Most ventilation ducts where large losses are expected to occur are located inside secured fences. There are a few examples where low energy operation may have large beam losses near ventilation ducts in unsecured areas. All ventilation ducts are in Controlled Areas while RHIC operates with beam. The locations for potential large beam losses near ventilation ducts outside of areas are the injection area and the abort kickers.

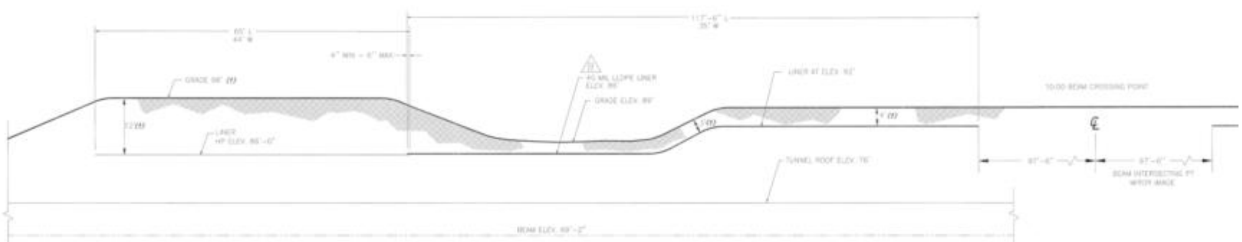

Figure I. Elevation view along the tunnel length at 10 O'clock.

There are six ducts at the 10 O'clock IR area that are not in a secured fence. They are the only ventilation ducts near an IR that are not in a secured area and four of them are close to the abort kickers. Figure I is an elevation view of the tunnel. A cross section of the area is shown in Figure II. Vents 9AV4, 10XSF1, 10XSF2, and 10AV1 are located in pairs on each side of the IR where the top of the berm is at elevation 89 feet above sea level. The XSF ducts have a diameter of 48 inches and a vertical shaft[7] of 20 feet. These are equivalent to the B-2 vent case given by A. Stevens[8] except the shaft is 4 feet longer. Thus one would estimate a dose of 230 mrem if half the beam faults near the vent. The other two vents have smaller diameter (42 inches) and a dose of about a factor of two smaller. The two vents near the intersection point, 10XEF1 and 10XEF2, have values of about one-half of 10XSF1 due to their larger distance to the beam pipe. These ducts have doses in scrapping faults similar to many of the other ventilation ducts.

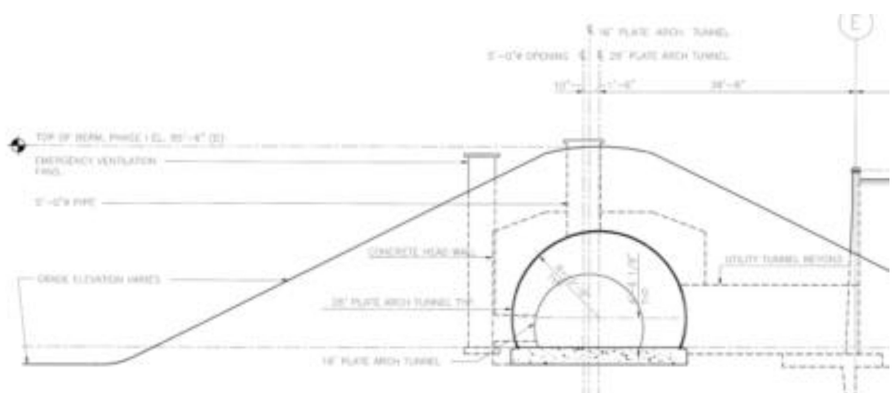

Figure II: Cross-sectional view transverse to the tunnel at 10 O'clock.

Ventilation ducts 10XSF1 and 10XSF2 are about ten feet downstream of the abort kickers. The abort kickers can be a source of potential chronic losses both at full energy and at low energy. A full beam loss at full energy occurring just past the end of the kicker could produce a dose of 500 mrem at the vent cover. This is in the upper range of the worst vents listed in Table I. However, the abort kickers are expected to be a potential loss point for scrapping especially for low energy operations, unlike almost all other locations near vents that are in open areas on the berm. Assuming that 25% of the 3.85 GeV beam losses occur on the abort kickers then a dose rate of 2 mrem/hr on the berm (vent cover) would occur at 10XSF1 and 10XSF2. The kicker position relative to the ventilation shaft has been taken into account. The beam losses on the kickers should be monitored closely and consideration given to enclosing the vents inside a secured fence.

Chronic doses rates from the vents near the kickers could contribute to the off-site dose. The distance from the vents to the site boundary is 1000 feet. Using a neutron attenuation factor[9] of 200 meters and scaling by $1/r^2$ to the site boundary a crude estimate of 0.006 mrem/week for 3.85 is obtained. This value assumes the 25% loss discussed and the reduction for the kicker location relative to the ventilation duct. The contributions from both vents near the kickers and both kickers have been included (two kickers on each side of 10 O'clock). The dose from the vents should not contribute substantially to off-site dose.

The RHIC beam dumps are 40 feet from the ventilation ducts 9AV4 and 10AV1. The ventilation shafts are in the backward direction. The beam dumps create a dose at the vents that is two orders of magnitude lower than compared to the kickers at low energies and therefore not considered an issue.

There are two ventilation ducts at the end of each injection hall that may be exposed to large dose rates from injection losses. Figure III provides a plan view of the 5 O'clock injection area. These ventilation ducts are listed as type F-2 in the RHIC documentation. The estimated DBA dose for these ducts is 132 mrem. However, this dose is from scrapping in the beam pipe adjacent to the vent. If one estimates the dose out the vent for the more likely loss position of the injection septum then a dose of rate of 1 mrem/hour is obtained for a 25% chronic beam loss. The skyshine[10] from the two vents to building 1005S would contribute a dose of 0.008 mrem per week at 3.85 GeV with a 25% loss on the injection magnets.

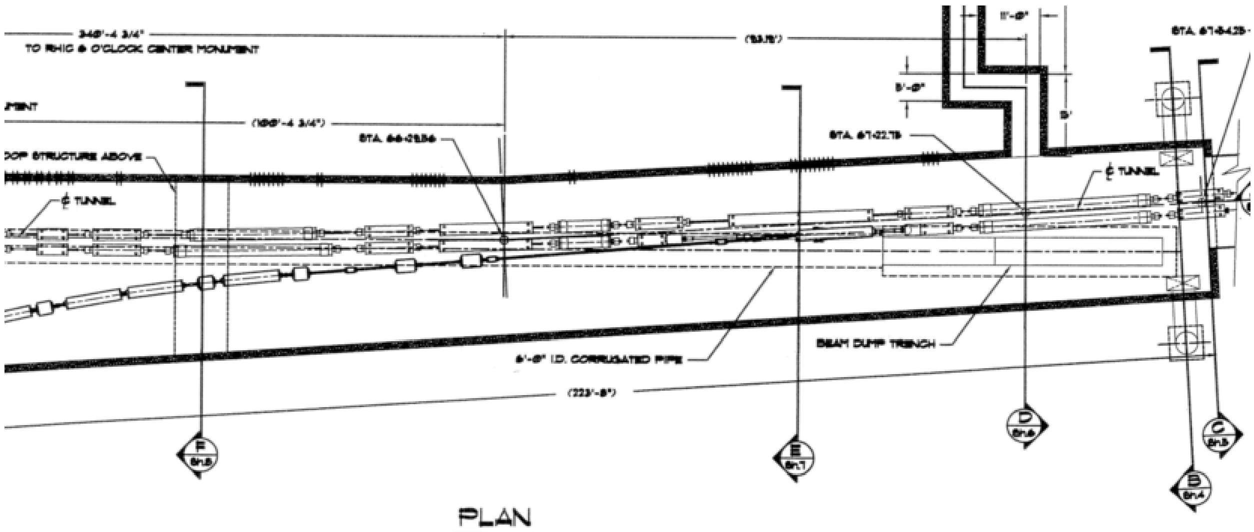

Figure III.: Plan View of the 1005 injection area.

Comments

The potential dose at the ventilation ducts around RHIC has been examined for possible low energy operations and possible future upgrades in intensity and energy. The estimates suggest that low energy operations are feasible this year for a period of weeks with modest monitoring in place. A phased approach seems a reasonable method to prepare for low energy operations. The following are suggested to be considered as part of the phase approach for reducing the risk of exposure near ventilation shafts for future operations of RHIC:

1) Document past Au and proton beam losses and their locations.
2) Re-examine the yearly amount of beam into RHIC for ions and protons.
3) Implement a monitor program using the loss monitor to monitor the losses for new modes of operations.
4) Implement surveys at ventilation shafts where losses are suspected to be large.
5) Select a few ventilation shafts for monitor TLDs to be placed for a dose history.
6) Consider enclosing the ventilation shafts with the largest risk inside secured fences.
7) Review the work controls for RHIC areas when beam is operating, especially for facility support functions.

References

1. RHIC SAD.
2. RHIC SAD Appendix 16.
3. M. Harrison and A. J. Stevens, "Beam Loss Scenario in RHIC", AD/RHIC/RD-52, January 1993.
4. RSC minutes of August 25, 2009 subcommittee meeting.
5. In reality the number of fill in previous operating years has been substantially lower.
6. T. Satogata, "RHIC Low Energy Beam Loss Projections", Sept. 9, 2005.

7. None of the shafts near the 10'Clock IR had dimensions on the drawing. Some error may be introduced by estimating the length of the vertical pipe. Diameters were measured in the field.
8. A.J. Stevens memorandum, "Dose at Exit of Duct Covers", August 28, 1998, also in appendix 16 of the RHIC SAD.
9. NCRP Report No. 144, <u>Radiation Protection for Particle Accelerator Facilities</u>, National Council on Radiation, 2003. See Figure 6.5. The value used is the 10 MeV neutrons.
10. A distance of 600 feet to building 1005S is used for the skyshine calculation. The other injection area is 1400 feet from 1005S and neglected. This is actually a direct shine estimate rather than a skyshine estimate.

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